

# A MIDDLE JURASSIC FLORA FROM THE WALLOON COAL MEASURES, MUTDAPILLY, QUEENSLAND, AUSTRALIA

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A Middle Jurassic impression flora from the Walloon Coal Measures near Mutdapilly in the Clarence-Moreton Basin, Queensland, comprises one equisetalean species, four species of ferns, and one species each of pentoxylalean, probable conifer, and possible bennettitalean foliage. The assemblage also contains a large number of *Palissya ovalis* cones of uncertain systematic affinity. The assemblage is similar to other fossil suites from the Walloon Coal Measures, but has fewer conifer and bennettitalean remains. It is most closely comparable to the flora of the Clent Hills Group (Bajocian-Bathonian) of New Zealand. □ *Middle Jurassic, fossil macroflora, Walloon Coal Measures, Clarence-Moreton Basin, sphenophytes, pteridophytes, Pentoxylales, conifers.*

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The Middle Jurassic flora of the Walloon Coal Measures is represented in coals (generally up to 2m thick) and interseam sediments. These coals have been exploited for over a century as a source of high volatile bituminous steaming coals (Fielding, 1993). Partial breakdown of the fossilized organic matter may also represent a potential source of liquid and gaseous hydrocarbons in deeper parts of the Surat and Clarence-Moreton Basins. Several palaeobotanical studies of the Walloon Coal Measures (notably Walkom, 1917; Gould, 1974, 1980; Rigby, 1978) have established the general composition of the flora. Gould (1974) provided a comprehensive list of previous palaeontological investigations of the coal measures. This study is intended to illustrate and describe a small assemblage of pteridophytic and gymnospermous taxa that occur as well-preserved impressions collected from a road cutting near Mutdapilly, southwest of Ipswich, Queensland. The Walloon Coal Measures flora is compared with several other Gondwanan Mesozoic fossil suites and its palaeoenvironmental implications are briefly considered.

## GEOLOGICAL SETTING

The Walloon Coal Measures of the Clarence-Moreton Basin consist of interbedded volcanolithic sandstone, coal, mudstone, and siltstone, reaching a maximum thickness of about 250m (Exon et al., 1974; Cranfield et al., 1976). They conformably and gradationally overlie the Lower Jurassic Marburg Formation (dominated by quartzo-feldspathic sandstones) throughout

much of the basin and are conformably or disconformably overlain by the ?Middle Jurassic to ?Lower Cretaceous Woodenbong Beds in the southern Clarence-Moreton Basin. The coal measures are locally overlain unconformably by Tertiary and Quaternary sediments and volcanics in the northern part of the Basin (Fig. 1). The coal measures extend into the eastern part of the adjacent Surat Basin and correlate with the Birkhead Formation in the western Surat and Eromanga Basins and with coal-rich units in the neighbouring Mulgildie (Mulgildie Coal Measures) and Maryborough (Tiaro Coal Measures) Basins. The Walloon Coal Measures palynoflora indicates a Middle Jurassic age (de Jersey, 1960; de Jersey & Paten, 1964; Burger, in Exon et al., 1974). Turner & Rozefelds (1987) recorded specimens of an actinopterygian fish from these strata. Dinosaur tracks are the only other fossils recorded from this unit (Bartholomai, 1966; Gould, 1974; Molnar, 1991).

Fielding (1993) identified seven sedimentary facies and three facies associations within the Walloon Coal Measures in the Rosewood-Walloon Coalfield. The facies associations are representative of major channel, floodbasin, and mire environments within a broad alluvial plain depositional setting. Limited palaeocurrent data suggested that streams in the northern Clarence-Moreton Basin generally drained in a southeasterly direction (Fielding, 1993). The Mutdapilly fossil plant assemblage was recovered from a roadcut at grid reference 692781 7465500 on the Ipswich 1:100 000 geological map (sheet 9442), (University of Queensland locality 5208) (Fig. 1).

The collection site is now obscured from view by groundcover vegetation and the Cunningham Highway.

#### MATERIAL AND METHODS

All specimens examined in this study are housed in the palaeontological collections of the Department of Earth Sciences, The University of Queensland, and are prefixed 'UQF'. The specimens were collected in the late 1980s from roadworks along the Cunningham Highway near Mutdapilly southwest of Ipswich, Queensland. The fossils are preserved as brown iron-stained impressions in yellow-grey shale and siltstone. No organic matter is preserved, preventing assessment of cuticular details. Forty-three slabs were considered in detail during this study; additional unfigured material is housed at the University of Queensland.

#### SYSTEMATIC PALAEOBOTANY

Phylum SPHENOPHYTA  
Class SPHENOPSIDA  
Order EQUISETALES  
Family EQUISETACEAE

*Equisetum* Linnaeus, 1753  
*Equisetum bryanii* Gould, 1968  
(Fig. 2A, B)

MATERIAL EXAMINED  
UQF79683, UQF79728.

#### DESCRIPTION

Incomplete segmented axes reaching in excess of 125mm long, width of flattened axis up to 8.5 mm. Axis more or less constant in width throughout with fine longitudinal striae, partitioned by transverse nodes 19-24mm apart (Fig. 2B). Whorl of elongate tooth-like flanged leaves surrounds each node (Fig. 2A). Around six leaves evident across stem impression (counterparts not available). Leaves closely adpressed to stem, extending 7-8mm distally beyond node, separated for 3-4mm below node. Leaves fused into a basal sheath tightly adpressed to axis and connected to stem at preceding (proximal) node. Leaf flanges continuous from base of sheath incision to apex. Midribs poorly defined. Fructifications and cuticular details unavailable.

#### COMPARISON AND REMARKS

Despite the absence of fertile material or cuticular detail, the described axes are assigned to *Equisetum* Linnaeus rather than *Equisetites* Sternberg following the conclusion of Harris (1961) and Gould (1968) that these genera are inseparable. The Mutdapilly specimens are readily referable to *E. bryanii* Gould by their smooth leaf sheaths and flanged, adpressed, free leaves with indistinct midribs. Specimens identified as *Equisetites approximatus* Halle 1913 from the mid- to late Mesozoic of the Antarctic Peninsula also show adpressed flanged leaves united into a long sheath and may be synonymous with *E. bryanii*. The absence of cuticular details and nodal diaphragms preserved in dorso-ventral view prevent detailed comparison to *Equisetum laterale* Gould 1974 but the latter can be distinguished by its more abruptly pointed leaves.

The Mutdapilly specimens are morphologically similar to extant *Equisetum* species and they probably occupied a similar ecological niche to extant species.

Phylum PTERIDOPHYTA  
Class FILICOPSIDA  
Order OSMUNDALES  
Family OSMUNDACEAE

*Cladophlebis* Brongniart, 1828  
*Cladophlebis australis* (Morris) Seward, 1904  
(Figs 2C-F, 3A-D, G)

MATERIAL EXAMINED  
UQF79680, UQF79681, UQF79684, UQF79686,  
UQF79688-UQF79691, UQF79694, UQF79700,  
UQF79704-UQF79706, UQF79723, UQF79729-  
UQF79733, UQF79736.

#### DESCRIPTION

Fronds at least bipinnate (Fig. 2C,F) reaching in excess of 135mm long, 160mm wide. Rachis reaching at least 5mm wide, tapering distally, smooth or longitudinally striate. Pinnae dimorphic (either fertile or vegetative). Vegetative pinnae lanceolate or falcate reaching 90mm long, 26mm wide, alternate to opposite (Fig. 2C,F), catadromous, rachilla departing rachis at 30°-65°. Pinnules subopposite, ovate or lanceolate (Figs 2E; 3A,C) and commonly arched distally (falcate) reaching 17mm long, 6mm wide, margin entire or slightly serrulate, apex pointed acute, acroscopic margin of pinna base slightly obcurrent joined with basisopic margin of adjacent pinnule base. Pinnule midveins depart rachilla at 40°-70°; lateral veins bifurcate once or twice

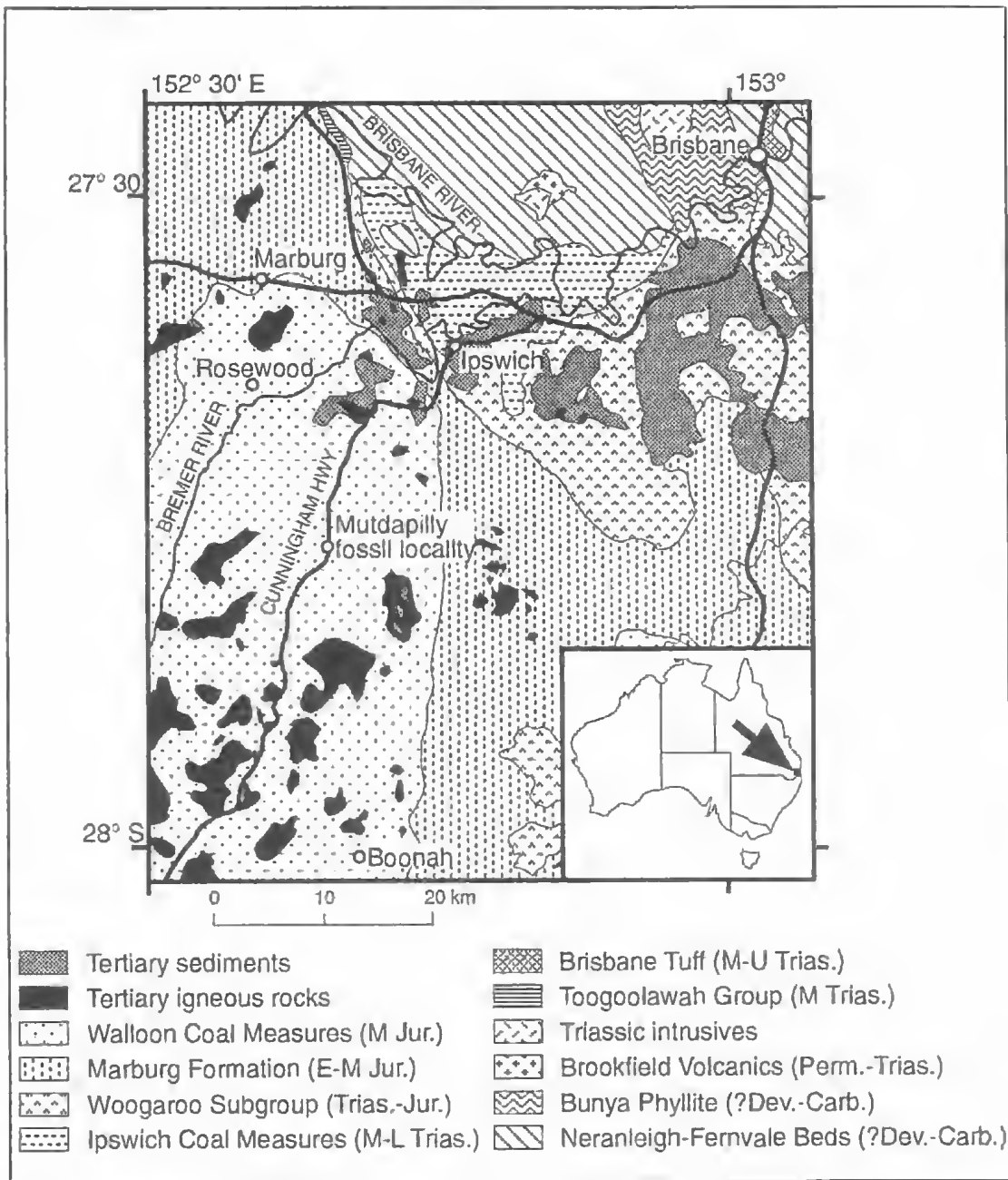


FIG. 1. Geological map of the Brisbane-Boonah district, southeast Queensland, showing location of the fossil locality at Mutdapilly, after Cranfield et al. (1976).

across the lamina. Sori or sporangia elliptical (0.4 x 0.5mm), striate, borne in clusters of 4-6 at the ends of veins on the abaxial surface of modified (fertile) pinnules (Figs 2D; 3G). Fertile pinnules equivalent in dimensions (or slightly narrower) and in arrangement to vegetative pinnules but

often flexed distally (Fig. 3D), lamina surface is slightly undulate, margin slightly incised (incisions <1mm) between lateral veins which do not bifurcate. Spores and cuticular details are not available on these specimens.

## COMPARISON AND REMARKS

*Cladophlebis australis* (Morris) Seward 1904 is one of the most widespread and abundant plant species in Australian Jurassic assemblages (Gould, 1975). There is considerable variation in size and shape of the pinnules amongst the Mutdapilly specimens (Figs 2E; 3A,C). Such morphological variants from individual localities have occasionally been assigned to a large number of species (e.g., see Halle, 1913) on inadequate criteria. Fronds and detached pinnae of *C. australis* are the most common plant remains in the Mutdapilly assemblage. It is not clear from the available material whether both fertile and sterile pinnae were attached to the same fronds. Fertile pinnae in the assemblage are either dispersed individually (Figs 2D; 3D,G) or attached to short rachis fragments (Fig. 3B). However, Walkom (1917: text-fig. 1) illustrated a fertile pinna of this species in which only the proximal pinnules were fertile.

*Cladophlebis* fronds have previously yielded sporangia containing osmundaceous spores (e.g., Harris, 1961) and the occurrence of abundant permineralized osmundaceous axes elsewhere in the Walloon Coal Measures, the similar shapes of the *C. australis* and *Osmundacaulis* petioles, and the clustered occurrence of some *Cladophlebis* fronds, strongly favours an osmundaceous affinity for *Cladophlebis australis* (Gould, 1973, 1974, 1980). The fertile pinnae described here show strong similarities to the osmundaceous fructification *Cacumen expansa* Cantrill & Webb 1987, which is probably affiliated with *Phyllopteroides* foliage. However, the Mutdapilly fertile pinnules appear to be bilaterally symmetrical with ranks of alternating sporangial clusters inserted on the abaxial surface either side of the midrib (Figs 2D; 3D,G) in contrast to the interpretation of *Cacumen* as bearing sporangia in radial arrangement about a reduced stalk-like pinnule proposed by Cantrill & Webb (1987). Similar sporangial arrangements to those suggested for the Mutdapilly fronds are evident on cladophlebid pinnae from the Australian and South African Triassic (Walkom, 1917, text-fig. 1; Anderson & Anderson, 1983, pl. 5, fig. 4; pl. 6, figs 4, 5).

*Cladophlebis* sp. A  
(Fig. 3E, F)MATERIAL EXAMINED  
UQF79679.

## DESCRIPTION

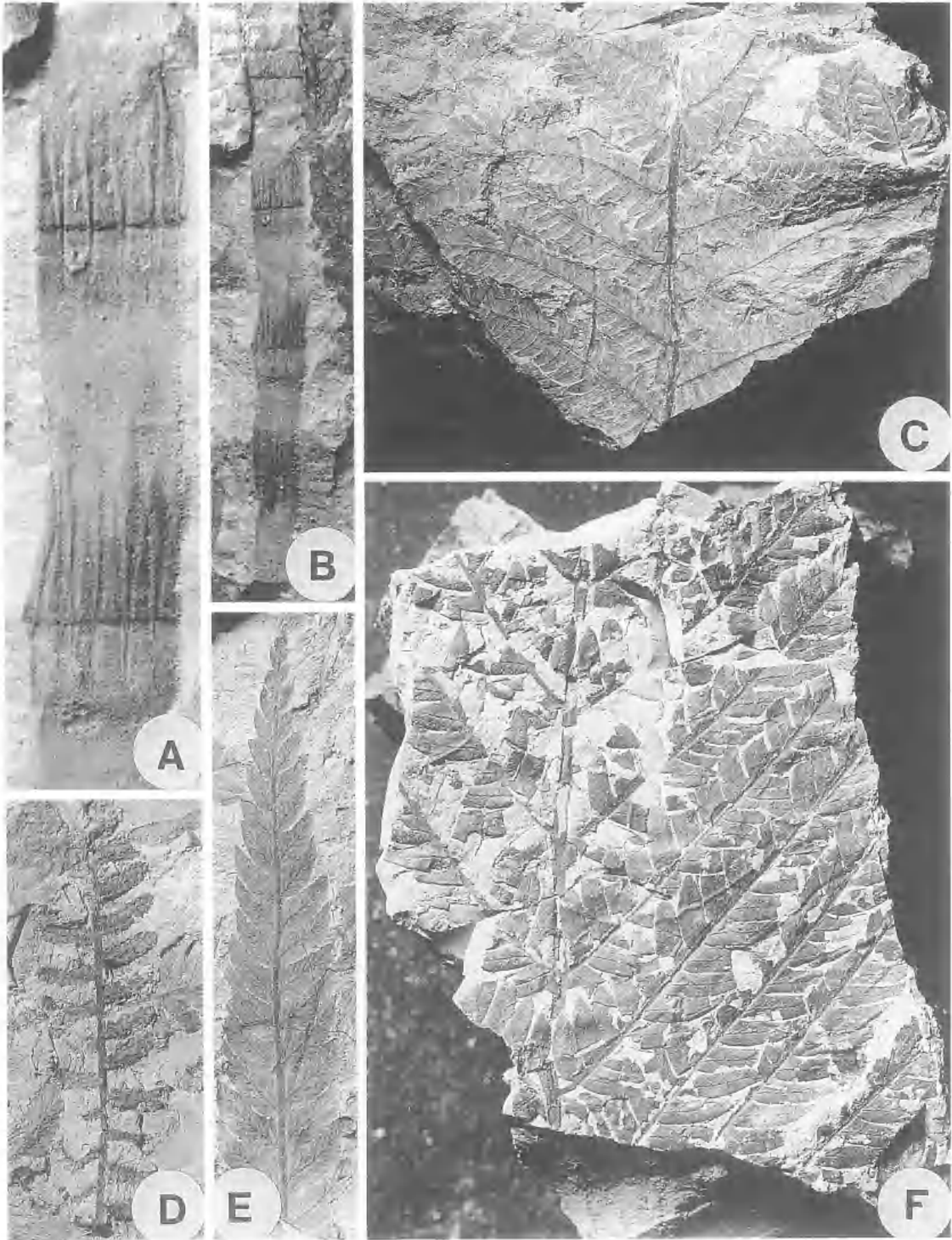
Frond at least pinnate, >5cm long, 2.5cm wide. Rachis 1mm wide at base of preserved frond, gently tapering distally. Pinnules ovate, decurrent, joined basally, subopposite, reaching 15mm long, 6mm wide. Pinnule margins lobed (Fig. 3E, F), apex rounded to pointed acute. Pinnule midribs prominent, slightly sinuous, arched sharply near base then passing along pinnule at 70°-80°, persistent. Pinnule venation basiscopic, lateral veins given off alternately at c. 40°-50° dichotomize once before margin, each vein pair entering a single marginal lobe (Fig. 3F). Cuticular details and fructifications unavailable.

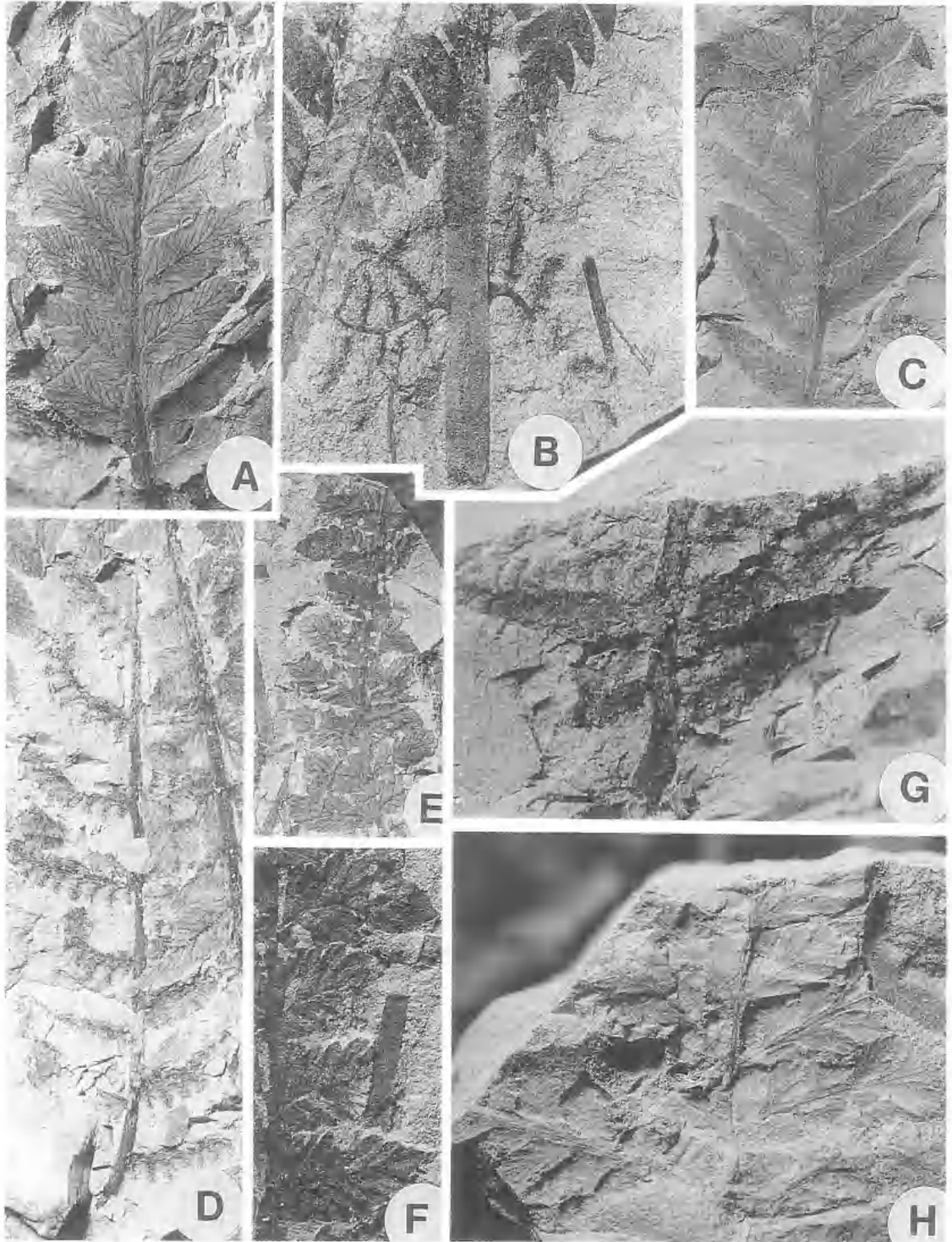
## COMPARISON AND REMARKS

Although only a single incomplete frond (with counterpart) of this species is available it is readily distinguished from *Cladophlebis australis* by its lobed pinnules each incorporating two ultimate veins. The prominence of the lateral veins together with inter-vein arching of the lamina imparts a crenulate appearance to the pinnules. These features distinguish this specimen from all other cladophlebid fronds previously described from the Australian Mesozoic. Fertile pinnules of *C. australis* are sometimes crenulate or irregularly lobed but they differ from *Cladophlebis* sp. A by their more slender and falcate shape and less distinct venation.

*Cladophlebis kathiawarensis* Roy 1968 is the most closely comparable Indian fern with pointed serrate pinnules. Although each serration on *C. kathiawarensis* pinnules incorporates two veins, the marginal cusps are strongly inclined, more sharply pointed, and not as deeply incised as the pinnule lobes on *Cladophlebis* sp. A. Herbst (1971) reviewed the Argentinian species of *Cladophlebis* and noted that only *C. mendozaensis* (Geinitz) Frenguelli possessed dissected pinnule margins that are gently undulate rather than distinctly lobed.

FIG. 2. A, B, *Equisetum bryanii* Gould, 1968, showing sheaths of partly fused lanceolate leaves around each node, UQF79683, A x 3, B x 1. C-F: *Cladophlebis australis* (Morris) Seward 1904. C, bipinnate frond with alternate pinnae, UQF79681, x 0.5. D, fertile pinna, UQF79728, x 1. E, sterile pinna showing variation in pinnule size, UQF79732, x 1.5. F, bipinnate frond with opposite to sub-opposite pinnae, UQF79700, x 1.





Order FILICALES  
Family DIPTERIDACEAE

**Hausmannia** Dunker, 1846  
**Hausmannia** sp. cf. *H. deferrariisii*  
Feruglio, 1937  
(Fig. 4A-D)

cf. *Hausmannia Buchii* (?) (Andrae), Walkom, 1917: 11; text-fig. 4.

*Hausmannia (Protorhipis)* sp. Hill, Playford, & Woods, 1966: pl. J1, fig. 9.

*Hausmannia* sp. cf. *H. (Protorhipis) deferrariisii* Feruglio, Gould, 1974: 35 (no figs).

*Hausmannia (Protorhipis)* sp. cf. *H. (P.) deferrariisii* Feruglio, Herbst, 1979: 18, figs. 4.12, 4.13, 6.13, 6.14; non fig. 1.6; Gould, 1980: 93, figs 6, 15.

MATERIAL EXAMINED

UQF79672-UQF79677, UQF79687, UQF79692, UQF79693.

DESCRIPTION

Fronds broadly reniform (auriculate) with a medial distal notch, auricles sometimes nearly touching (though never fused) to give a bi-lobed circular to peltate appearance to the frond (Fig. 4B-D). Petiole (rachis) attachment in centre of frond lamina. Lamina reaching 117mm wide, 45mm from distal margin to petiole insertion, 31mm from petiole insertion to proximal margin of auricles. Distal medial cleft up to 15mm deep. Lamina symmetrical about the plane from petiole insertion to distal cleft. Petiole >17mm long, reaching at least 3 mm wide at connection with lamina. Petiole midvein bifurcates at base of lamina giving off a vein to each half of lamina. Each daughter vein then bifurcates up to seven times across lamina producing a radial array of tuning fork shaped principal veins which evanesce 2-5mm from margin (Fig. 4A,D). At least three further orders of subsidiary veins divide the intervening lamina into polygonal meshes. Apart from medial distal cleft, lamina margin entire or gently undulate with short (<2mm) notches between principal vein groups (Fig. 4A,D). Marginal vein present <0.2mm wide.

COMPARISON AND REMARKS

Mutdapilly fronds vary in size but show a consistently bi-lobed reniform shape. The relatively thick petiole attached to one specimen is also a feature that may be taxonomically important.

Herbst (1979) reviewed the previously described and illustrated Australian specimens of *Hausmannia* and concluded that three species (viz., *H. wilkinsii* Walkom, *H. sp. cf. H. deferrariisii* Feruglio, and *H. bulbaformis* Douglas) remained valid. *Hausmannia bulbaformis*, established for two specimens from the Victorian Early Cretaceous (Douglas, 1969), differs from the material described here by its more flabellate rather than reniform shape and its more dissected margin. *Hausmannia wilkinsii* can also be differentiated by its strongly dissected fronds (Walkom, 1928, Herbst, 1979). Herbst (1979) included both Middle Jurassic and Early Cretaceous forms within *Hausmannia sp. cf. H. deferrariisii*. However, the Early Cretaceous fronds from Western Australia and the Northern Territory illustrated by White (1961a, 1961b, 1966), now supplemented by better material housed in the Western Australian Museum, do not show the auriculate base characteristic of the Queensland Jurassic representatives of this species and should be transferred to a separate species.

*Hausmannia papilio* Feruglio from Argentina typically has a truncate base (Longobucco et al., 1985), but some examples illustrated by Herbst (1960) have a rounded auriculate base not dissimilar to the Mutdapilly specimens. Fertile material is not available in the Queensland assemblage preventing closer comparison to the Argentinian forms. *Hausmannia cf. nariwaensis* Oishi from the Hope and Botany Bay floras (Rees, 1993) of the Antarctic Peninsula differs from the Mutdapilly species by its greater length:width ratio and more prominently crenulate margins.

*Hausmannia pachyderma* Sukh-Dev 1971 and specimens assigned to *Hausmannia crenata* (Nathorst) Möller from India (Bose & Sah, 1968) do not show the strongly auriculate base or the deep apical cleft of the Mutdapilly specimens. The Indian *H. crookshanki* Shah & Singh 1964 is similar in shape to *H. sp. cf. H. deferrariisii* but differs in being substantially smaller with fewer principal veins which do not bifurcate as often across the lamina.

FIG. 3. A-D, G, *Cladophlebis australis* (Morris) Seward, 1904. A, pinna showing details of venation, UQF79731, x 1.5. B, Two fertile pinnae attached to thick rachis, UQF79690, x 2. C, sterile pinna with entire-margined pinnules, UQF79691, x 1.5. D, fertile pinna with flexed pinnules, UQF79704, x 2. G, portion of fertile pinna, UQF79686, x 4. E,F, *Cladophlebis* sp. A, showing pinnules with lobed margins, UQF79679, E x 1, F (counterpart) x 2. H, *Sphenopteris* sp., UQF79699, x 1.5.

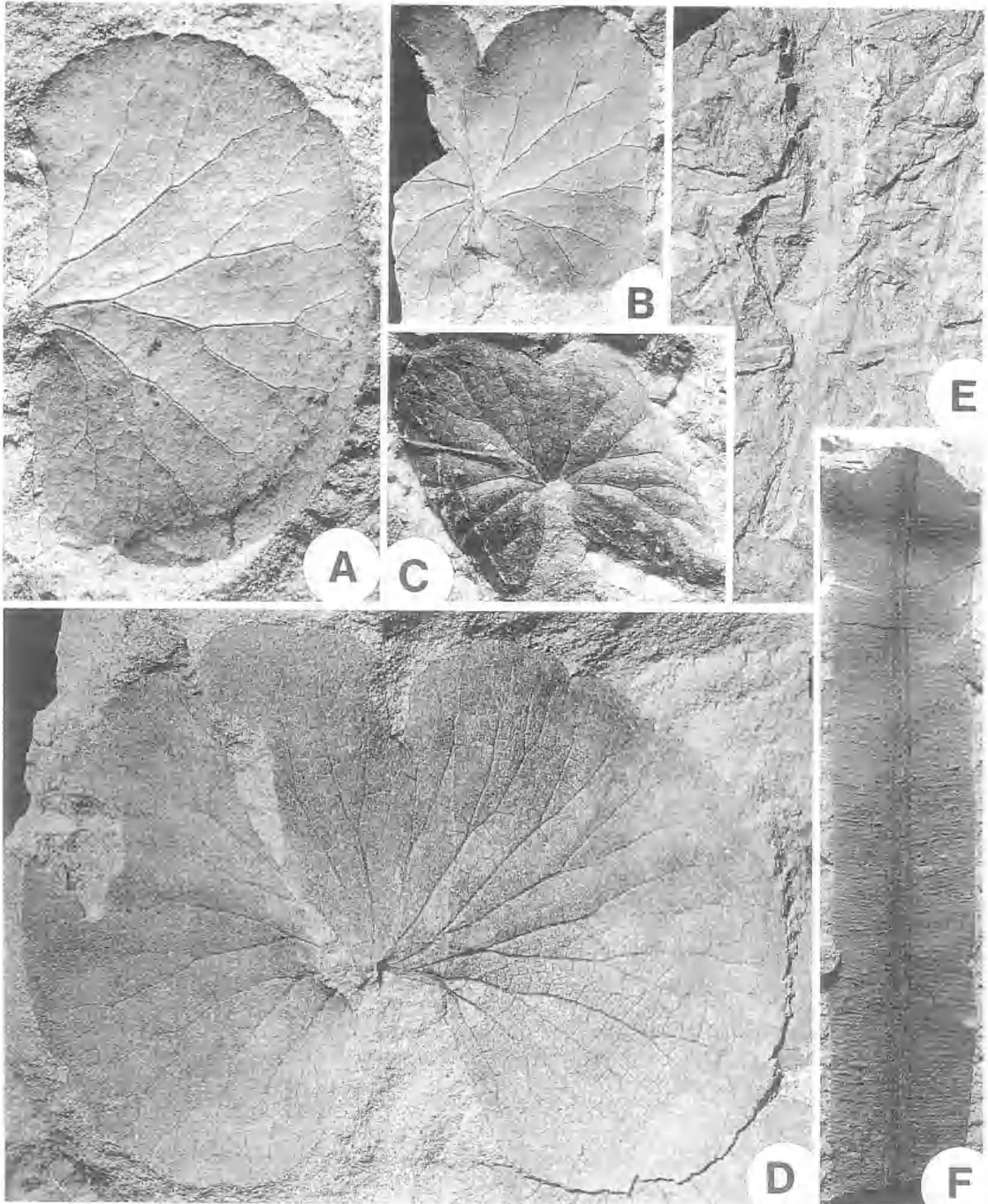


FIG. 4. A-D, *Hausmannia* sp. cf. *H. deferrariisii* Feruglio, 1937. A, half frond showing venation details, UQF79672, x 2. B, UQF79673, x 1. C, UQF79674, x 1. D, large reniform frond, UQF79687, x 1. E, F, *Taeniopteris* sp. cf. *T. spatulata* McClelland, 1850. E, matted examples of very slender leaves, UQF79707, x 1. F, broad leaf showing venation details, UQF79721, x 2.



## INCERTAE SEDIS

**Sphenopteris** (Brongniart) Sternberg, 1825**Sphenopteris** sp.  
(Fig. 3H)MATERIAL EXAMINED  
UQF79699.

## DESCRIPTION

Frond at least bipinnate, rachis impression with central ridge flanked by thin (<0.5mm) marginal flanges. Pinnae incomplete (>20mm long, 9mm wide), catadromous, opposite to subopposite, probably ovate to elliptical. Pinnae rachilla depart rachis at 55°-70°. Pinnules ovate to elliptical, alternate, decurrent, reaching 9mm long, 3mm wide, dissected <20% into rounded distal lobes each with an ultimate vein (Fig. 3H). Midvein sinuous, undergoing unequal dichotomies 3-4 times along pinnule. Pinnule midrib departs rachilla at 20°-40°. Fructification and cuticular details unavailable.

## COMPARISON AND REMARKS

The single available specimen (Fig. 3H) is referable to *Sphenopteris* because of its bipinnate frond and dissected pinnules with sinuous veins. However, the scant remains prohibit confident specific identification. Fronds attributed to *Coniopteris delicatulata* (Shirley) Walkom 1917, *Coniopteris hymenophylloides* var *australica* Seward (Walkom, 1919), *Coniopteris hymenophylloides* Brongniart (Walkom, 1921) and *Coniopteris* sp. (Hill et al., 1966) probably from the basal Jurassic Landsborough Sandstone of the Nambour Basin, the Purlawaugh Formation of central New South Wales, and the Woodenbong Beds (or Grafton Formation) and the Walloon Coal Measures of the Clarence-Moreton Basin, are possibly conspecific with the Mutdapilly specimen. However, the absence of fertile material does not permit definite assignment to *Coniopteris*. Other Mesozoic Australian sphenopteroid fronds [e.g., *S. lacunosa* Shirley 1898, *S. warragulensis* McCoy 1892, *S. flabellifolia* (Tenison-Woods) Walkom 1919] differ by their less dissected or more elongate pinnules. *Sphenopteris travisii* Stirling 1900 has similar dissected pinnules but these are not so attenuated at the base as those of the Mutdapilly specimen.

INCERTAE SEDIS  
Order PENTOXYLALES  
Family PENTOXYLACEAE**Taeniopteris** Brongniart, 1828  
**Taeniopteris** sp. cf. *T. spatulata*  
McClelland, 1850  
(Figs. 4E,F, 5A,B)MATERIAL EXAMINED  
UQF79707-UQF79710, UQF79715-UQF79721,  
UQF79724, UQF79726.

## DESCRIPTION

Leaves highly variable in size and shape, spatulate (Figs 4F; 5A,B) to linear (Fig. 4E), reaching 124mm long, 13mm wide, lamina entire, arrangement on stem uncertain. Lamina very gently tapering towards base, apex rounded acute. Midrib stout, reaching 2mm wide at base, tapering gently towards apex, persistent, longitudinally striate. Secondary veins depart midrib at 80°-90°, typically bifurcating immediately on leaving the midrib then passing straight to margin or bifurcating once more in outer lamina (Figs 4F; 5B). Vein concentration 25-36 per cm at margin. Cuticular details and fructifications unavailable.

## COMPARISON AND REMARKS

*Taeniopteris* leaves from Triassic to mid-Cretaceous Australian deposits show a strong degree of morphological conservatism, differing only slightly in their average sizes and the angle of secondary vein departure from the midrib. Features such as the shape of the leaf apex and the entirety of the lamina margin are variable within populations (Drinnan & Chambers, 1985) and are probably not useful taxonomic features. Cuticular details and the morphology of associated fructifications may be important characters for the specific segregation of *Taeniopteris*-bearing plants but these features are commonly not available. *Taeniopteris* and *Nipaniophyllum* leaves have consistently been found in association with *Carnoconites* (ovulate) and *Sahnia* (pollenate) fructifications from various Gondwanan provinces (Sahni, 1948; Vishnu-Mittre, 1953; Drinnan & Chambers, 1985, 1986) and most are likely to belong to pentoxylalean gymnosperms. *Taeniopteris* leaves from the Walloon Coal Measures have traditionally been referred to *T. spatulata* (e.g., Walkom, 1917; Hill et al., 1966; Gould, 1980), a species established for Jurassic to Early Cretaceous Indian material. Queensland and Indian leaves are morphologically very sim-

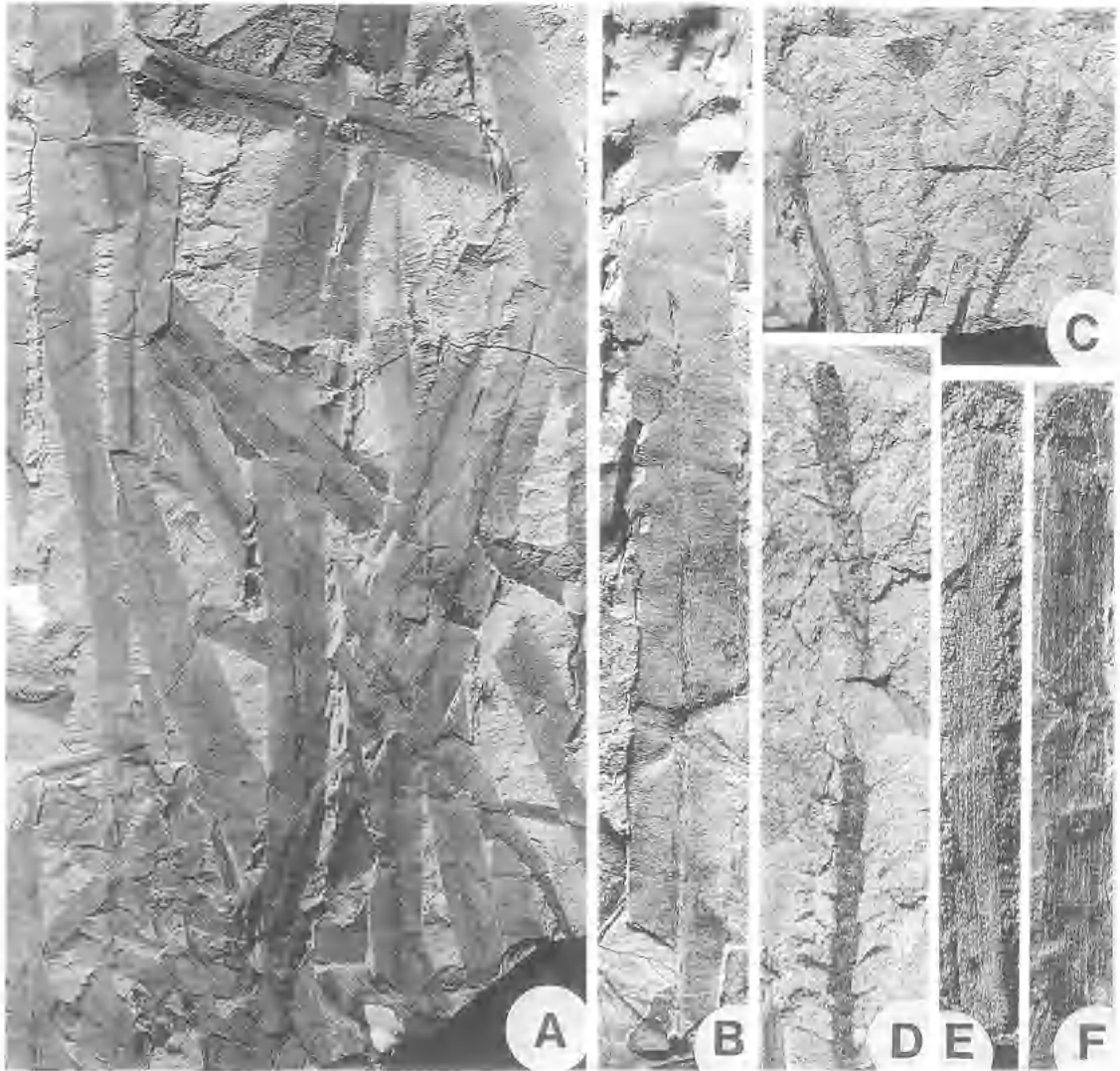


FIG. 5. A,B, *Taeniopteris* sp. cf. *T. spatulata* McClelland, 1850. A, matted examples of relatively broad *Taeniopteris* leaves, UQF79718 (right), UQF79719 (centre), UQF79720 (far left), x 1. B, UQF79715, x 2. C,D, cf. *Elatocladus confertus* (Oldham & Morris) Halle, 1913. C, several slender, rarely branched, twigs with spirally inserted uni-veined leaves, UQF79696, x 1. D, enlargement of one axis in Fig. 5C, x 3. E,F: indeterminate parallel-veined foliage. E, UQF79714, x 2. F, UQF79735, x 1.5.

ilar, but the Walloon specimens lack critical cuticular data, anatomical details, and fructifications that now appear to be essential for accurate specific determinations within this genus. Most Australian Triassic *Taeniopteris* leaves (e.g., *T. carruthersi* Tenison-Woods 1883, *T. lentriculiforme* (Etheridge) Walkom 1917, *T. dunstani* Walkom 1917) differ from *T. sp. cf. T. spatulata* by their proportionately broader laminae and lesser vein density.

*Taeniopteris* leaves from Mutdapilly range from relatively broad spatulate forms (Figs 4F; 5A,B) to linear, needle-like examples (Fig. 4E). Although individual leaves can appear quite different, a morphological continuum exists within the population. A similar morphological range is evident in *Taeniopteris* leaves from the Clent Hills Group (Middle Jurassic), Waikawa, New Zealand. *Taeniopteris daintreei* McCoy 1860 and *T. howardensis* Walkom 1919, from the Victorian and Queensland Early Cretaceous respec-

tively, also show close morphological similarities to *T. sp. cf. T. spatulata* but as Drinnan & Chambers (1985) implied, the relationships between the middle and late Mesozoic pentoxylaleans will only be clarified with the discovery of associated fructifications.

#### INCERTAE ORDINUS

***Elatocladus* Halle emend. Harris, 1979**  
 cf. ***Elatocladus confertus***  
 (Oldham & Morris) Halle, 1913  
 (Fig. 5C, D)

MATERIAL EXAMINED  
 UQF79696.

#### DESCRIPTION

Slender axes (>30mm long, <2mm wide), some showing irregular branching, bearing numerous widely spaced spirally arranged linear to oblong leaves (Fig. 5C,D). Leaf scars transversely elliptical, reniform, or slit-like. Leaves reaching 8mm long, 0.8mm wide, flattened, univined, margin entire, apex rounded, lower part of leaf gently tapering but base slightly expanded, clasping? or slightly decurrent. Leaves arched basally to depart stem typically at 40°-80°. Attached fructification and cuticular details unavailable.

#### COMPARISON AND REMARKS

The few available slender axes show narrow flattened univined leaves typical of *Elatocladus* or *Rissikia* species. Leaves and leaf scars on the axes (Fig. 5D) indicate spiral leaf insertion but, owing to indifferent preservation, it is unclear whether the leaves were naturally twisted to lie in a single plane or whether the distichous arrangement is due to compression. These leaves are significantly smaller than those traditionally attributed to *Elatocladus plana* (Feistmantel) Halle and lack the contracted lamina base typical of that species. Although the leaves are slightly more sparse than previously figured examples, the Mutdapilly fossils are closest to *Elatocladus confertus* (Oldham & Morris) Halle 1913. Sterile *Elatocladus* remains have traditionally been regarded as coniferous and have sometimes been compared to the Podocarpaceae. However, *Elatocladus*-type remains have previously been found associated with *Palissya* (Edwards, 1934) and sometimes assigned to that genus (Shirley, 1902) although a physical connection between sterile foliage and fertile cones has not been dem-

onstrated. As the structure of *Palissya* is atypical for conifers we suggest their placement together with *Elatocladus* under open nomenclature until their phylogenetic affinities are more clearly resolved. The common association of *Elatocladus* foliage with *Palissya* cones in Australian and New Zealand Jurassic and Cretaceous deposits supports an affinity between these fossils. However, other plant remains (notably *Taeniopteris* species) are also co-preserved with these fossils and are possible candidates for foliage associated with *Palissya*.

#### INCERTAE ORDINUS Family PALISSYACEAE

***Palissya* Endlicher, 1847**  
***Palissya ovalis* Parris,**  
 Drinnan & Cantrill, 1995  
 (Fig. 6A-I)

#### MATERIAL EXAMINED

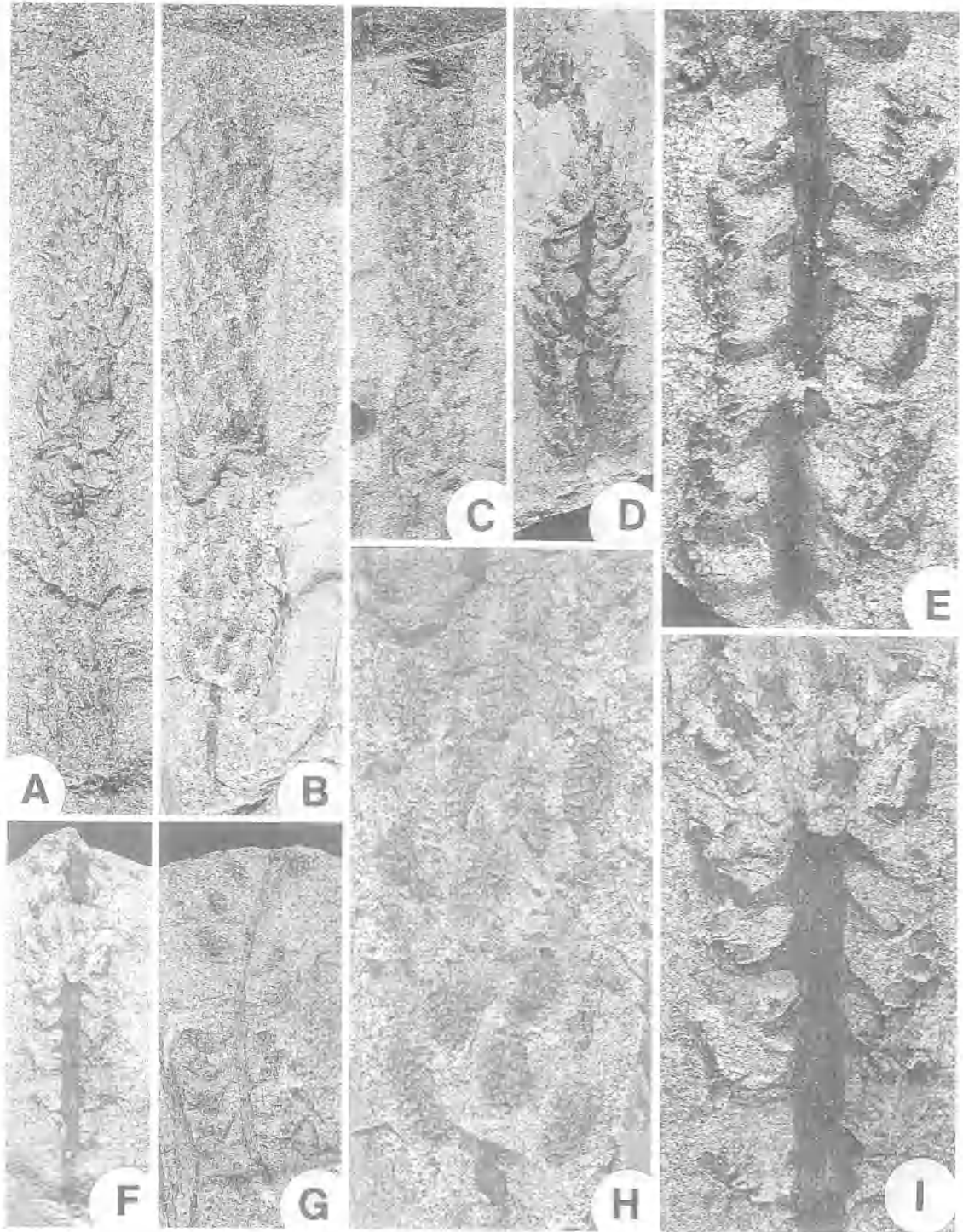
UQF79671, UQF79678, UQF79682, UQF79685,  
 UQF79695, UQF79697, UQF79698, UQF79701-  
 UQF79703, UQF79722, UQF79727.

#### DESCRIPTION

Elongate cone greater than 120mm long, 14mm wide, consisting of a central axis up to 2.5mm wide, bearing helically arranged sporophylls. Sporophylls stalked, oval, lamina up to 5mm long and 2.5mm wide, stalk 4mm long. Sporophylls bear 7 or 8 pairs of adaxial processes.

#### COMPARISON AND REMARKS

None of the cones are complete, but several seem to be missing only a relatively small proximal portion. Some specimens are cleaved longitudinally through the cone (Fig. 6D-G,I), revealing the axis and sporophylls in longitudinal section. In others, the part and counterpart have separated close to the surface of the cone, revealing details of the cone in surface view (Fig. 6A-C, H). Cones are preserved in both closed and open states. In closed cones the sporophylls are tightly overlapping and closely appressed to the cone axis (Fig. 6A-C). In most of these specimens, cleavage of the part and counterpart has occurred around the surface of the cone through the sporophyll blade, revealing a prominent dendroid pattern on the abaxial surface of the sporophylls (Fig. 6H). This pattern results from pairs of overlapping adaxial cup-shaped processes that remain embedded in the part when the sporophyll blade separates with the counterpart (Parris et al., 1995). In open cones, the sporophylls have re-



flexed away from the axis and the sporophylls and their adaxial processes are often visible in lateral view (Figs 6D-G,I). These processes were interpreted by Parris et al. (1995) as probably associated with ovules or seeds, but there was no conclusive evidence of any attached sporangiate structures in any of the species of *Palissya* that they examined, nor are they apparent on the Mutdapilly cones discussed here.

These cones are very similar to *Palissya ovalis* described by Parris et al. (1995) from several other southeast Queensland localities in the Walloon Coal Measures. The few specimens of *P. ovalis* previously available show only five or six pairs of adaxial processes per sporophyll, whereas specimens from Mutdapilly, which are more numerous and complete, have seven or eight pairs of processes per sporophyll (Fig. 6H). However, this may reflect that the small sample of the original *P. ovalis* material was too fragmentary to reveal accurately the sporophyll detail. There are also some minor differences in sporophyll size, but these alone are not sufficient to warrant status as a separate species. *Palissya bartrami* Edwards 1934 from the Middle Jurassic of New Zealand is similar in size and gross morphology, but the specimens examined by Parris et al. (1995) appeared to have only three or four pairs of sporophylls. Because of the similarity of the Mutdapilly cones to *P. ovalis* from elsewhere in the Walloon Coal Measures, we have assigned the Mutdapilly cones to that species. Future accumulation of specimens from Australia and New Zealand will almost certainly necessitate a revision of the taxonomy of *Palissya*.

#### INCERTAE SEDIS

Parallel-veined foliage/axes  
(Fig. 5E, F)

#### MATERIAL EXAMINED

UQF79711-UQF79714, UQF79725, UQF79734, UQF79735.

#### DESCRIPTION

Linear leaves/axes reaching at least 80mm long, 5mm wide, margin entire, apex rounded,

base unavailable, arrangement on axis unknown. Venation parallel, dichotomous?, vein concentration 4-9 per 2mm measured transverse to venation. Indistinct linear striations common on lamina between veins. Lamina sometimes split longitudinally between the veins.

#### COMPARISON AND REMARKS

All specimens are fragmentary. Some undoubtedly represent leaves or detached pinnules with rounded apices (Fig. 5E) whereas others (Fig. 5F) may constitute portions of longitudinally striate rachises or axes. Several specimens show longitudinal splitting of the lamina/axis between the veins. The specimens are reminiscent of detached cycadalean or bennettitalean pinnules but none can be identified with certainty. However, the absence of other recognizable pinnate cycadophytic foliage in this assemblage is notable given its frequent occurrence elsewhere in the Walloon Coal Measures and lateral equivalents (Gould, 1974, 1980) and in Middle Jurassic strata of other parts of the world.

#### DISCUSSION OF THE FLORA

The abundant, relatively complete remains of ferns and equisetaleans preserved within fine-grained sediments accords with the low-energy paludal/lacustrine depositional environments suggested for parts of the Walloon Coal Measures by Exon et al. (1974) and Cranfield et al. (1976). *Taeniopteris* leaves are also well-represented on several bedding planes. While Gould (1974, 1975, 1980) noted that remains of pteridophytes and pentoxyleans were locally abundant (especially near the base of coal seams) he indicated that the flora of the coal measures as a whole was dominated by araucarian and podocarp conifers. The notable absence of pinnate cycadophyte fronds and pachypterid seed ferns so common to other Australian Jurassic assemblages may indicate deposition away from better drained sites (where those plants may have been more abundant). Nevertheless, common *Palissya* cones and scarce *Elatocladus*-like foliage together with isolated parallel-veined leaflets constitute minor though significant conifer and possible pterido-

FIG. 6. A-I, *Palissya ovalis* Parris, Drinnan & Cantrill, 1995. A, cone exposed by fracturing through the sporophyll blades, UQF79678, x 1. B,H, near-complete cone with up to eight pairs of overlapping cup-shaped processes on each sporophyll exposed by cleavage through the sporophyll blades, UQF79695, B x 1, H x 3. C, UQF79701, x 1. D,E, cones exposed by cleavage along axis, showing recurved sporophylls and adaxial cup-like processes, D, UQF79722, x 1, E, UQF79685, x 3. F,I, axially cleft, open cone, showing details of recurved sporophylls, UQF79671, F x 1, I x 3. G, open cone, UQF79702, x 1.

sperm components of the flora. Ginkgophytes are notably absent from the Mutdapilly collections. This absence was also recognized from other Walloon Coal Measure assemblages investigated by Gould (1974, 1980) and is surprising given that group's abundance and virtually cosmopolitan distribution in the Jurassic.

The preserved foliage yields little definitive information concerning the palaeoclimate during deposition of the Walloon Coal Measures. *Taeniopteris* leaves in the assemblage frequently occur as complete leaves in matted layers (Figs 4E, 5A) consistent with their interpretation as the foliage of deciduous pentoxylaleans (Drinnan & Chambers, 1985, 1986). The probable deciduous character of these plants together with distinct growth banding evident in pentoxylalean and conifer woods elsewhere in the Walloon Coal Measures (Gould, 1980) suggests some climatic seasonality but whether the plants were responding to variation in rainfall, temperature, photoperiod or some other environmental factor is indeterminable. Modern dipteridacean ferns occur only in subtropical to tropical humid environments (Corsin & Waterlot, 1979). It is possible that extinct representatives of this family such as *Hausmannia* sp. cf. *H. defarrariisii* were also restricted to humid megathermal-mesothermal habitats although the latitude of the Moreton Basin during the Jurassic was probably around 60° (Embleton, 1984) or as high as 65°-75° (Smith et al., 1973).

Floristic similarities are evident at the generic level between the Middle Jurassic Mutdapilly assemblage and Australian Early Jurassic and Late Jurassic to Early Cretaceous floras, but differences are generally evident at species level. Notable differences are the appearance of *Hausmannia* ferns, the scarcity of phlebopterid ferns, and the apparent absence of *Sagenopteris* in the Walloon flora compared to Early Jurassic assemblages (Walkom, 1917; Jones & de Jersey, 1947; Gould, 1974, 1975, 1980). Late Jurassic floras are poorly known from the Australian region although Day (1964) recorded an assemblage from the Surat Basin's Orallo Formation that is similar to the Walloon Coal Measures apart from the presence of ginkgoaleans. Early Cretaceous floras commonly differ either by the occurrence of more abundant bennettitalean remains or by the presence of ginkgoaleans, phyllopteroid ferns, and herbaceous isoëtalean lycophytes (Walkom, 1928, 1944, Glaessner & Rao, 1955; Douglas, 1969; Gould, 1978; Drinnan & Chambers, 1986).

A strikingly similar flora to the Mutdapilly assemblage was described by Edwards (1934) from the Clent Hills Group, Waikawa, New Zealand. The New Zealand assemblage, regarded as Middle Jurassic (Bajocian-Bathonian) by Arber (1917), Edwards (1934), and Suggate et al., (1978), yields similar equisetalean axes, sphenopterid remains, cladophleboid fronds, taeniopterid leaves, *Palissya* cones, and *Elatocladus*-type foliage to the Mutdapilly flora. The Waikawa assemblage differs by the presence of lycophyte axes, pinnate Bennettitalean fronds, and ?araucarian remains and by the absence of dipteridacean ferns.

The Hope and Botany Bay floras of the Antarctic Peninsula long considered to be Late Jurassic or Early Cretaceous in age have recently been regarded as Early Jurassic or older (Rees, 1993). These Antarctic Peninsula floras contain similar, but mostly not identical, forms of *Equisetum*, *Cladophlebis*, *Sphenopteris*, *Hausmannia*, *Otozamites*, *Elatocladus* and *Pagiophyllum* species to the Walloon assemblages and differ in also yielding *Sagenopteris*, *Pseudoctenis*, and *Goepfertella* and by lacking *Taeniopteris* (Gee, 1989; Rees, 1993). The occurrence of *Sagenopteris* and *Goepfertella* foliage in the Hope/Botany Bay assemblages reflects closer similarities to the flora of the Early Jurassic Marburg Formation of the Clarence-Moreton Basin (Gould, 1971).

## CONCLUSIONS

The Mutdapilly plant fossil assemblage is rich in pteridophytes (most notably *Cladophlebis australis* and *Hausmannia* sp. cf. *H. defarrariisii*) and probable pentoxylaleans (*Taeniopteris* sp. cf. *T. spatulata*). *Palissya* cones are also abundantly represented in the assemblage. The flora differs from typical Walloon Coal Measure suites by a deficiency in bennettitalean and conifer (especially *Araucaria*, *Allocladus*, and *Pagiophyllum*) species. The Mutdapilly assemblage is most similar to those described by Gould (1980) from the base of coal seams elsewhere in the Walloon Coal Measures and perhaps reflects a specialized pioneer mire community. In other respects the assemblage has elements in common with a number of Middle Jurassic Gondwanan floras, reaffirming the age assigned to the Walloon Coal Measures by previous palynological and stratigraphic studies. The flora provides little definitive palaeoclimatic information but a moist seasonal climatic regime is envisaged based on the categories

of plants preserved, the apparent deciduous character of *Taeniopteris* leaves, and prominent growth rings evident in permineralized wood elsewhere in the Walloon Coal Measures.

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